Flight Systems Research Quarterly

An informal newsletter by and for participants of the UCLA/NASA Flight Systems Research Center

Volume 1 Issue 4 Summer 1994

Higher but not Faster

Aviation progress has historically followed a path of developing aircraft capable of flying higher and faster than their predecessors. This trend has been modified from time to time, as aircraft designers have sought to emphasize such improvements as maneuverability and survivability. But the aim of higher and faster has always been of prime importance. And in almost all cases, the driving force behind a new, pioneering aircraft program has been a military-related application.

Over the last five years, however, the requirements for a new airplane have arisen which break with tradition. Higher altitude, yes; but faster speed, no. And the motivation this time (at least initially) is from the scientific community.

At a recent conference sponsored by NASA's Ames Research Center (see NASA CP 10041), the requirements for a very high altitude subsonic aircraft for atmospheric research were discussed and defined. Three motivating factors have pointed to the need for such an aircraft.

First, the marked success of NASA's ER-2 science platform airplane has shown the usefulness of making highly controlled, high-resolution, in-situ measurements in atmospheric regions of special interest. The ER-2, which has a cruise altitude of nearly 70,000 feet and a range exceeding 3000 miles, has answered important questions about the stratospheric ozone balance that were unanswerable by other techniques.

Second, there remain key scientific questions that can be addressed only with improved aircraft ceiling and range, and with payloads similar to those of the ER-2. One mission is to continue to study the polar vortex, trying to answer such questions as: "What causes ozone loss above the dehydration region in Antarctica?" and "To what extent are

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UCLA Students Spend Summer at Dryden

This summer, seven UCLA students came to work at NASA's Dryden Flight Research Center at Edwards AFB under sponsorship of the UCLA Flight Systems Research Center. More than just a summer job to complement their academic studies with real world technical problems, their work was directly related to either their graduate research theses or undergraduate research projects. Living in the Antelope Valley and coming to Dryden daily, they worked alongside NASA engineers and accomplished tasks which otherwise would not have been possible had they not been on-site. In the paragraphs which follow, their efforts and contributions are summarized. (the editor gratefully acknowledges their input for the following...)

In front of NASA's legendary X-1E are: (L to R) Polwin Chan, John Griswold, Aaron Bachelder, Christina He, Eric Shank, Brian BJ Petersen, and Walter Chung.

Brian "BJ" Petersen, a first-year graduate student in the MANE department studying under advisor Prof. Ann Karagozian, spent the summer working in the aerodynamics branch. His grant technical monitor was Dr. Tony Whitmore. The majority of his time was spent on formulating a sliding window Fourier Transform algorithm and spectrum visualization. A graphical programming language called LabVIEW was used to develop the algorithm. The window slides along the time history of a given data set and calculates the spectrum for each window. At time zero

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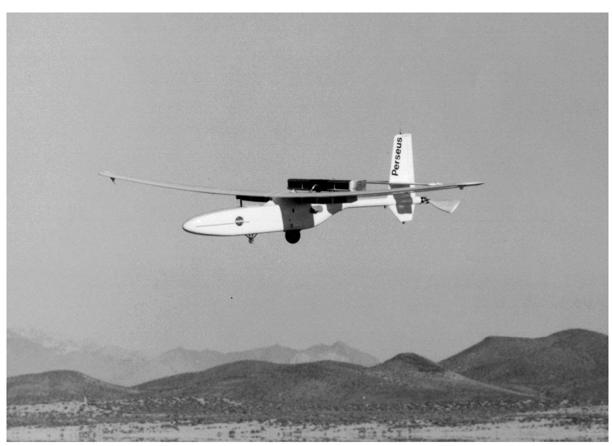
dehydration, denitrification, and ozone loss transmitted to midlatitudes?". A second mission is to analyze the high-altitude photochemistry in tropical and middle latitudes. The goal here is to determine if the abundances of O3, O, OH, HO2, NO, NO2, Cl and ClO quantitatively account for the photochemical state of the middle and upper stratosphere, as a function of altitude, latitude, and measured solar flux. The need to fly (often over water) vertical profiles down to 33,000 feet and have a zoom-up capability to altitudes of 115,000 and 130,000 feet make this mission unsuitable for traditional high-altitude balloons. A third mission is to examine the transport of chemical species by general global circulation. Over the lifetime of the winter vortex, how much air is chemically processed and transmitted to midlatitudes? What is the chlorine content and what are its chemical forms in the tropical middle stratosphere? How are the estimated lifetimes of chlorofluorocarbons affected by the diabatic cooling rates in and around the winter vortex? A fourth mission is to study the volcanic, stratospheric cloud/aerosol, greenhouse, and radiation balance. How do volcanic injections affect the chemistry of trace gases, including ozone, and radiation and temperature fields? What do stratospheric profiles of radiative fluxes and radiatively active constituents, in conjunction with tropospheric profiles, reveal about the onset and predicted evolution of the greenhouse effect? Such a mission would require an altitude zoom up capability as well as flight over vast regions of water far from land. In many cases, flight into the polar night would also be necessary.

The third motivation for this aircraft is the current status of high-altitude aircraft technology. Current state-of-the-art knowledge in the critical engineering disciplines exist to provide the necessary technology for a scientific aircraft operating subsonically at 100,000 feet. However, sustained level cruise or jump-up or zoom up maneuvers to 120,000 feet (subsonically) are problematic. Moreover, subsonic flight at 130,000 feet will require major technological advances.

Undaunted, several small aerospace firms within the last 5 years have already taken the initial steps toward meeting that requirement. Companies such as Aurora Flight Sciences with their Perseus A and B aircraft and Aerovironment with their Pathfinder aircraft hope to explore flight at altitudes between 65,000 and 85,000 feet. Both of these aircraft have flown and are currently being flight tested (envelope expansion) at NASA Dryden Flight Research Center.

But an aircraft that meets the specifications desired by the atmospheric science community -- one that can carry a 3000-lb payload subsonically for a total range of 6000 miles over land and water, day and night, at a cruise altitude of 100,000 feet, with a zoom up capability to 120,000 or 130,000 feet -- is still years away.

Convinced of the very real environmental, scientific, and technological issues at stake, NASA headquarters has placed the Dryden Flight Research Center in a leading role to take such an aircraft from the drawing board to the air. Located at Dryden is the newly formed Environmental Research Aircraft and Sensor Technology (ERAST) Program, a consortium of government, industry, and academic team members focused on development of the aircraft, which will most likely be an unmanned aerial vehicle (UAV) in its first form, unlike the manned ER-2. A name for the aircraft is also still to be determined, though some have suggested an X-plane designation. One thing which is certain, though, is that the answers to the myriad engineering questions surrounding the challenging program will require diverse approaches and pioneering efforts by all those involved. (Please see related article "APEX: A First Step", page 3.)



The Perseus "A" has reached over 50,000 feet during envelope expansion flights.

The regular column, "Research Roundup", does not appear in this issue in lieu of the 1994 Research Review (see below).

Research Review '94

The 1994 UCLA Flight Systems Research Center Research Review meeting will be held Thursday and Friday October 20-21 at the Valencia Hilton Resort Hotel from 9:00am - 4:00pm each day. During the two-day meeting, FSRC graduate students will be making presentations of their research activity over the last year. A compendium of all the talks will be available after the meeting for those interested.

Given the fact that classes continue to take place during the 2-day meeting, proper arrangements should be considered early. For presentation scheduling information, please call the UCLA FSRC contact, Ms. Barbara Tennison of the EE Department at 310-825-2854 to avoid any unnecessary conflicts. Refreshments and lunch will be provided by the Hilton.

The *FSRC Quarterly* is published during the Fall, Winter, Spring, and Summer quarters for participants of the UCLA/NASA FSRC.

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the algorithm is seeded by performing a regular FFT. In subsequent time frames the previous Fourier transform along with the window time history beginning and ending points are used to calculate the Fourier transform in the current window. This algorithm saves computation time and allows for reasonably fast visualization of the spectrum data as the window slides along the time history. This visualization tool has application to boundary layer transition analysis for identifying unstables modes and the evolution of flow disturbances in time. Using hot-film anemometry data from the F-16XL supersonic laminar flow control aircraft, BJ identified an esoteric instability mode which, if analyzed using a conventional non-sliding FFT, would have been dismissed as merely random data noise.

John Griswold, a senior undergraduate in MANE, has been working this summer on the analysis of pressures on the wing and tail surfaces of the F/A-18 High Alpha Research Vehicle (HARV) in order to determine whether or not they are the cause of anomalous flying qualities at high angles of attack. John has written a program as an offshoot of work done previously by Bob Geenen (NASA/XRA), who worked on the HARV's forebody and leading edge extensions. To date, John has been developing the graphical user interface (on a Silicon Graphics IRIS) to aid in the analysis and integration of pressure data on the wings' moving control surfaces. The program allows the user to customize the display to better interpret the pressure data. In additon to his regular classes, John plans to work through Fall quarter to finish the analysis on the HARV's tail surfaces, as well.

Walter Chung worked on analytical redundancy, fault detection, and health monitoring for aircraft with Professor Jason Speyer from the MANE department.

NASA-UCLA Colloquium '94 Minutes

This past June 3rd, 16 professors and 33 graduate students representing five departments from UCLA attended the NASA-UCLA Colloquium '94 held at Dryden. The all-day meeting consisted of presentations from each of the branches of the Research Engineering Division. Division Chief, Dwain Deets, was the moderator. The Dryden speakers highlighted areas of active and growing research, and invited the UCLA academic community to participate in the endeavors.

The Colloquium began with a welcome and introduction by Dryden Center Director, Ken Szalai, wherein he encouraged the growing cooperative relationship between the university and NASA. Tony Whitmore of XRA began the series of technical talks with a presentation on research efforts and needs in the areas of aerodynamics and fluid mechanics. Steve Johnson of XRP followed with an overview of current acitivity in the aircraft propulsion and performance branch. Rod Bogue of flight instrumentation (XRF) also spoke to the crowd of UCLA and Dryden personnel. After a lunch break, Pat Seamount from the controls branch (XRD) and Karl Anderson from aerostructures (XRS) gave informative presentations on their respective areas. The day ended with impromptu meetings between UCLA researchers and NASA engineers, in addition to a walking tour of the Center. *(Special thanks to Ms. Lesa Marston of PRC-Dryden for preparation and organization of the meeting.)*

APEX: A First Step

In support of the ERAST/UAV aircraft program, Dryden engineers have taken a first step toward designing an aircraft capable of flight at extreme altitudes with the APEX (Aerodynamic and Propulsion EXperiment) airplane. Not intended to be the final aircraft desired by the science community, APEX will serve as an aerodynamic research test bed that would efficiently collect low-turbulence, low Reynolds number, transonic flight data at altitudes between 65,000 and 100,000 feet. This data would be used for validation and calibration of wind-tunnel and computational models of both the aircraft flight dynamics (simulator model) and airfoil aerodynamics (CFD code). These results would in turn lead to the development of the final product, an effective high-altitude aircraft for atmospheric research and other science applications.

Timely acquisition of baseline aerodynamic flight data is critical to the ongoing design and development efforts for high-altitude aircraft. Deploying an aerodynamic research aircraft such as the Apex with a high-altitude balloon has great potential for acquiring baseline aerodynamic flight data very quickly. Working in conjunction with the proven balloon-deployment capability of the National Scientific Balloon Facility (through NASA Goddard Space Flight Center, Wallops Island Facility) and eliminating the time associated with the complex development of a high-altitude power-plant, a balloon-deployed research aircraft can acquire the desired aerodynamic flight data sooner and more cost-effectively.

Between 1991 and 1992, engineers at Dryden conducted a piloted simulation study for the high altitude balloon-deployed Apex aircraft (see NASA TM 104245) Essentially a feasibility study, the authors investigated various launch (from balloon) options, the pull-out maneuver and flight profile, and simulator and aerodynamic models. The conclusion was that the objectives of Apex could be achieved with an unmanned, modified sailplane, carried to 110,000 feet with a balloon, and released in a nose-down attitude. A remote pilot would control the aircraft through a pullout and execute a zoom climb to a trimmed, 1-g flight condition, attaining an altitude of approximately 95,000 feet. The effects of various small parachutes and rocket motors on the maximum attainable stabilized altitude were also examined. This paper study remained dormant until June of 1994, when the ERAST alliance adopted the Apex proposal as a useful and important first step on the engineering road to their final product.

As of October 1994, the Dryden Apex team is hoping to present a preliminary design review shortly. With a fuselage already selected and much of the instrumentation, range and meteorology, and flight controls issues addressed, what remains is a thorough analysis of the structural and aerodynamic characteristics of the main wing. Predicting a successful PDR, the team is looking toward a first flight in January 1996.

Part of the Apex team includes professors and graduate students from UCLA. At a recent meeting at Dryden, several professors involved in the Flight Systems Research Center were briefed on critical research areas that could benefit from university collaboration. Professor Jason Speyer of the MANE department, along with graduate student Polwin Chan have already begun investigating optimization of the launch trajectory and dynamics (see UCLA article on page 1). Professor Speyer is also looking at the dynamic control of aircraft wing flutter. Professors Peretz Friedmann and Oddvar Bendiksen are interested in Apex's unique aeroelastic and aerostructures problems. Assistant Professor Xiaolin Zhong is working with NASA aerodynamicist Bob Geenan to perform a rarefied flow CFD analysis of the proposed Apex wing planform and airfoil to determine if the L/D is sufficient for high altitude flight. Given the important value of university involvement, UCLA may be working closely with the Apex program and the eventual science-application high altitude aircraft for some time to come.

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During his three month stay, Walter Chung looked at developing a health monitoring system for aircraft structures. A health monitoring system is a dedicated and autonomous system of sensors and microprocessors that checks the aircraft for failures and abnormalities. Chung and Speyer are investigating an approach that estimates the states of the aircraft structure. Processing the residuals of these estimators extracts information on its health (i.e. whether or not cracks or corrosion exist in the structure). Already, this research has led to new results which extend the existing theory of decentralized estimation. A paper detailing these findings has been submitted to the American Controls Conference. In the year to come, work will commence on a experiment which will apply health monitoring to a simple plate and to data from a test on an F-18.

Polwin Chan, also a graduate student in MANE working with Professor Speyer, spent his time at Dryden developing optimal control strategies for the APEX, a high altitude balloon-launched glider aircraft to be built at Dryden within the next year. (see APEX artile on p. 5) Piloted simulation had previously produced some feasible pullout trajectories from 110,000 feet after a nosedown balloon-launch. The size and release time of the parachute were fixed just large enough to keep the aircraft speed below its prescribed Mach 0.7 limit. The dynamics in pitch were described by a full 5-state model with assumed aerodynamic (coefficients) data. Optimization of the elevator control for this maneuver was investigated. The nonlinear optimal control problem of maximizing the total energy at the final trimmed, 1-g condition was solved numerically. First-order gradient methods were used to compute control variations from the local stability and control derivatives. The resulting flight trajectories, while approaching the optimum, leveled out more quickly to satisfy the 1-g terminal constraint. Methods to determine future control strategies and initial drop heights for APEX flights were also studied because the actual research aircraft has not been completely designed yet. Polwin's NASA technical monitor was XRA's Jim Murray.

Aaron Bachelder worked on a CS 199 undergraduate project under Prof. Walter Karplus titled: Analysis of Attention Sharing and Augmented Reality for the X-31 Heads-Up Display (HUD). Aaron investigated the visual domain separation characteristics of current HUD systems. Recognizing the inherent attention switching nature of the HUD, he has prototyped an augmented reality cockpit display that uses real world indicators instead of artificial (two-dimensional and monochrome) numerical gauges. He has found that these "out-the-window" indicators, such as virtual clouds, seem to enhance situational awareness during unusual attitudes and low visibility flight. Tracking real-world objects also appears to be more efficient and safe, as is seen on landing approaches with attitude and altitude indicators placed on the runway. Although the display seems to lack the precision of current HUD systems, experience with the augemented reality display has shown noticable flight performance improvement. Unlike current HUD systems, the augmented reality display provides attention sharing functionality and high-level information for enhanced pilot awareness and safety.

Rockwell / MBB **X-31** in flight with thrust-vectoring engaged.

Eric Shank, graduate student in CS with Prof. Karplus, is working on a new research effort to determine whether sound spatialized in 3 dimensions is an effective tool in the management of complexity in high-workload environments. A machine called the Convolvotron, provided by the X-31 program, creates virtual sound sources located in arbitrary positions in three dimensional space. Once mixed, the user hears the sound through conventional headphones. Eric's first project is to spatialize the several channels of audio in the control room. Spatialized audio should induce the "cocktail party effect" in which listeners filter out the channel of interest from a cacophony of simultaneous conversations. Subsequently, he will renew work on audio radar displays presenting information on the location of other aircraft to pilots in much the same way as a mosquito can be located by its characteristic buzz. Eric remains in residence at Dryden through the fall season. Mary Shafer of XRDC is technical monitor for both Eric and Aaron Bachelder.